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Impact of climate change induced hazards on the livelihood of marginalized coastal dwellers of West Bengal, India

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Abstract: The tropical coastal regions are severely vulnerable to climate change and associated hazards, having a major impact on global hydrological cycle from the last three decades, with subsequent enhancement of hazards. Tidal inundations and the saline water intrusions are responsible for the disaster in coastal areas of West Bengal making people susceptible to livelihood hazards by affecting the agricultural land resources which transform into saline land resulting in joblessness and income reduction. Storm Surge and cyclonic high-speed wind break the weak river embankments, resulting in inundations. So, the aim of the study is to unfold the effect of inundation due to super cyclone Amphan and Yash on the livelihood of the rural people, in Ramnagar I & II Blocks, of Purba Medinipur, West Bengal, India. NDVI during the years 2000, 2010 and 2022 reveal a decline in the values, ranging from -0.54 to +0.7 in 2000, -0.239 to +0.55 in 2010, and -0.16 to +0.51 in 2022, showing a gradual reduction in agricultural productivity during 2000 to 2022. Notably, the most pronounced changes in NDVI values occur between the coastline and 25 to 30 kilometers inland, an area where soil salinity has had a detrimental impact on the land. NDVI values have steadily decreased from 2000 to 2022, indicating reduced agricultural productivity. Agricultural land has decreased by 62.36%, while water proportions increased by 71.2% and rural settlements decreased by 37.64% due to water inundations during the period 2010 to 2022. Likewise, 6% of the respondents became jobless during post-disaster phase.

Keywords: Climate change; livelihood; geospatial; saline water intrusion; tidal inundation

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1. Introduction

The shifting patterns of climate represent one of the most significant phenomena observed in the last three to five decades. Numerous studies indicate that climate change is predicted to accelerate the global hydrological cycle (Parvin et al., 2016). Over recent decades, there has been a gradual increase in sea level rise, flooding, storm surges, and other climatic disasters, particularly affecting Low-lying coastal regions, which are the most vulnerable to these changes (Younus et al., 2014). West Bengal, as a low-lying developing region, is especially at risk from climate change. Additionally, the geographical density of the population, coupled with poverty, makes coastal communities particularly susceptible to these impacts. Among the various climatic risks and disasters, super cyclones, cyclones, and storm surge floods are the most common and recurrent occurrences (Rayhan et al., 2010), posing a significant threat to coastal expansion (Paul et al., 2010 & Younus et al., 2013). It is estimated that 70% to 80% of the population in West Bengal, particularly in rural coastal areas, faces the risk of storm surge flooding (Cash et al., 2015). The floods induced by climate change have severely affected the lives and livelihoods of people, especially in rural coastal regions (Parvin et al., 2016). Globally, flood-related (UNISDR,2013) disasters have increased over the past thirty to fifty years, and the Bay of Bengal's coastal area is no exception to this trend due to climate fluctuations (Rayhan et al., 2010). West Bengal, characterized by its floodplain nature, is situated in a river delta with numerous river basins (Paul et al., 2010). The scale, intensity, and duration of floods are likely to alter land use patterns in Purba Medinipore's coastal areas in West Bengal, potentially resulting in significant harm to agriculture, housing, and other sectors. Different societal segments experience climate-related hazards unevenly, with the poorest communities suffering the most severe impacts (United Nations, 2009; Yodmani, 2001; Johnson, 2006). Consequently, low-income individuals are often the most affected by floods and other climate-induced disasters, as they frequently lack the resources to implement protective measures and struggle to recover from losses in property and income (Brouwer et al., 2007). The interdependence between poverty and frequent flooding contributes to a vicious cycle within society (Armah et al., 2010). The effects of climatic disasters are particularly pronounced on economically disadvantaged populations and rural residents, undermining both their social and economic well-being. The destruction from climate-induced disasters impacts agricultural yields, livestock, household infrastructure, water supply, transport and communication systems, educational institutions, and essential services. As a result, the effects on society, the economy, and infrastructure exacerbate the vulnerability of the rural impoverished populace. These communities confront significant challenges in sustaining their livelihoods amidst persistent climate adversities. Gaining insights into how climate hazards specifically affect the livelihoods of the rural poor and their resilience strategies is essential for the development and implementation of effective mitigation programs as conditions change. Such understanding can improve coping mechanisms for the impoverished, protecting them from further vulnerabilities arising from floods (Parvin et al., 2016). The coastal region of Purba Medinipur faces challenges due to climate change and climatic hazards, including rising sea levels and increasing soil and water salinity, which significantly degrade crop quality. Moreover, alterations in fishing patterns and serious disturbances to hydrological conditions have devastating effects on fishermen. Frequent cyclones and unpredictable monsoonal rains, along with other climatic anomalies, threaten both ecology and human livelihoods (Mahadevia et al., 2010). Flood-induced climate threats disrupt the socioeconomic environment. Floods can lead to the destruction of natural and man-made resources, social infrastructures, cultural traditions, economic viability, agriculture, transportation, and various other aspects of human life and livelihoods (Billa et al., 2006; Messner & Meyer, 2006; Huang et al., 2008).

Climate change poses (Barros et al.,2014) a significant threat to the livelihoods of marginalized coastal communities worldwide, with Purba Medinipur, a coastal district in West Bengal, India, being particularly vulnerable. These communities face rising sea levels, increased storm frequency and intensity, and erratic precipitation, all of which are drastically altering their environmental and socio-economic landscapes. Notably, there is a gap in understanding the specific challenges faced by these communities, especially regarding climate change's impact on agriculture and food security due to soil salinization. Recent decades have seen a gradual rise in sea levels, flooding, and other climate-related disasters disproportionately affecting low-lying coastal regions, which are the most susceptible to such changes (Younus et al., 2014). West Bengal, as a developing low-lying area, is at high risk from these phenomena (Aleem et al., 2023). High population density and widespread poverty exacerbate the vulnerability of coastal communities, making them more susceptible to events like super cyclones and storm surges. It is estimated that 70% to 80% of West Bengal’s rural coastal population is at risk from storm surge flooding (Cash et al., 2015), resulting in substantial impacts on their livelihoods (Parvin et al., 2016). Globally, incidents of flood-related disasters have been on the rise over the past thirty to fifty years, and the Bay of Bengal region is no exception (Rayhan et al., 2010). West Bengal’s geography, characterized by river deltas and numerous basins, makes it particularly vulnerable to flooding, altering land use patterns and potentially harming agriculture and housing (Paul et al., 2010). Different socio-economic segments experience climate-related hazards unevenly, with poorer communities facing the most severe consequences due to limited resources for protective measures and recovery (Brouwer et al., 2007). This interdependence of poverty and flooding creates a vicious cycle of vulnerability (Armah et al., 2010).

The impacts of climate change are profound, affecting livestock, household infrastructure, and essential services, thereby exacerbating the challenges faced by the rural poor. Understanding how climate hazards specifically affect these communities and their coping strategies is crucial for developing effective mitigation programs. This knowledge can help build resilience against future flooding and other climate-related disasters (Parvin et al., 2016).

In Purba Medinipur, challenges such as rising sea levels and increasing soil and water salinity degrade agricultural productivity and food security. Changes in fishery patterns and disruptions to hydrological conditions have negative consequences for local fishermen. Recurring cyclones and unpredictable monsoonal rains further threaten both the ecosystem and local economies (Mahadevia et al., 2010). Flood-related climate threats lead to the destruction of natural and human-made resources and cultural traditions, critically undermining economic viability and disrupting daily life (Billa et al., 2006; Messner & Meyer, 2006; Huang et al., 2008). This study aims to fill the existing knowledge gap regarding the impact of climate change on marginalized coastal communities in Purba Medinipur. It will specifically examine the effects of soil salinization on agricultural productivity, food security, and overall livelihoods. By investigating the complex relationships between climate change, soil salinization, and community livelihoods, the research aspires to develop effective adaptation strategies prioritizing the needs of marginalized coastal dwellers. The novelty of this work lies in its specific focus on the unique challenges faced by these communities and the empirical evidence it seeks to provide regarding the effects of climate-induced hazards on their livelihoods.

1.1. Objective

1. To analysis the variations of land cover and land use map of the year 2022, 2010 and 2000 by using geospatial technology.
2. To examine the changes of percentage of land use area.
3. Assessment of impact of climatic hazard (cyclone, super cyclone, extremely severe cyclone) on coastal dwellers.
4. Changing pattern of occupational structure of coastal dwellers.

The goal of the present investigation was to analyses the influence of climatic hazard on livelihood of rural people in Ramnagar I & II Blocks, of Purba Medinipur. In the study data of satellite images of 2000, 2010, 2022 has been adopted to recognize the modifications of land use pattern.

1.2. Study area

This study aims to illustrate the nature and causes of floods resulting from storm surges in the Ramnagar 1 and Ramnagar 2 blocks of the Purba Medinipur district in West Bengal, specifically focusing on severe climatic hazards that have occurred over the past five years (Yash, Amphan, Bulbul, Fani) (Figure 1). This chapter discusses the impact of these climatic hazard-induced floods, particularly saline water inundation, on the lives of rural and economically disadvantaged communities. By emphasizing rural poverty, the study examines the effects of floods and the resilience strategies employed by these communities, taking into account their socio-economic conditions. In this context, "coping mechanisms" refer to the strategies that people adopt to effectively manage crises (Armah et al., 2010).

The study area is located in the Purba Medinipur District, situated in the southern part of West Bengal. This region covers an area of 4,151.64 km^2 (Mondal, 2012) and lies between latitudes 21°38’ N to 22°31’ N and longitudes 87°27’ E to 88°12’ E (Mondal, 2012). It is bordered by the Ghatal Subdivision of the West Medinipur District to the north, the Bay of

Bengal to the south, the West Medinipur District to the west, and the Hooghly River to the east (Mondal, 2012). The area comprises four subdivisions: Contai, Haldia, Tamluk, and Egra (Mondal, 2012). The coastal region features dune formations, interspersed with fluvial and aeolian sediments (Mondal et al., 2013). Several tidal channels, such as Sankarpur Khal, Jalda Khal, and Ramnagar Khal, divide the area (Mondal et al., 2013). The coastal zones of Ramnagar 1 and 2 are prone to cyclones, susceptible to erosion from sea tides and dune migration. The local climate has contributed to the development of Digha-Sankarpur as a popular summer resort, with average temperatures reaching 30°C from March to June and falling to around 20°C in winter (November to February). The monsoon season is generally associated with depressions, which rarely escalate to cyclonic storms. At least one severe cyclone has occurred in this coastal zone every five to ten years. High-intensity cyclonic storms typically originate in the Bay of Bengal and impact this area during the monsoon, pre-monsoon, and post-monsoon periods. Coastal agriculture faces significant productivity challenges due to salinity in water and soil, exacerbated by climate-related disasters such as storm surges and cyclones (Sadik et al., 2018). During cyclones like Yash, Amphan, Fani, and Bulbul, severe storms and tidal surges breached embankments, leading to saline water intrusion into agricultural fields and aquaculture farms, which extended the duration of waterlogging. This influx of saline water rendered both soil and water saline (Sally et al., 2018), causing crop failure and leaving farmland barren and unproductive. Consequently, agricultural laborers experienced substantial losses in crop yields. While cultivators attempted to grow alternative crops, persistent waterlogging has resulted in land degradation (Ahsan et al., 2019).

Purba Medinipur district, located in coastal West Bengal, faces numerous challenges, including underdevelopment, limited agricultural advancements, a significant amount of unirrigated land, a lack of alternative income sources, high vulnerability to environmental risks, a fragile resource base, and heavy reliance on underdeveloped agriculture (Mondal, 2012). Covering an area of 4,295 km^2, the district is situated along the Bay of Bengal and within the lower Gangetic plain, geographically located between 21°36'35"N to 22°02'23"N and 87°22'48"E to 88°01'12"E (Mondal, 2012). It is bordered by West Medinipur and Howrah to the north, the Bay of Bengal to the south, South 24 Parganas and Howrah to the east, and the state of Odisha to the west, with a total population of 5,094,238 (Mondal, 2012). The population density is 1,076 people per km^2 (Census, 2011). The terrain is primarily flat with moderate runoff, averaging 5-7 meters above sea level, and a slope ranging from 0 to 5 degrees. The district experiences high tides that contribute to drainage problems in low-lying areas (Mondal, 2012). The main rivers in this region include Rupnarayan, Kasai-Haldi, and Keleghai. Due to its fluvio-tidal location, the area is subject to high tides that cause drainage congestion in low-lying regions (Mondal, 2012). The soils in the district are largely alluvial. Major issues include waterlogging and related flooding, along with the inundation of saline water from the sea, which constitutes a primary concern in the study area (Mondal, 2012).

This study investigates the nature and causes of flooding due to storm surges in the Ramnagar 1 and Ramnagar 2 blocks of the Purba Medinipur district in West Bengal. It focuses on recent significant climatic events over the past five years, namely cyclones Yash, Amphan, Bulbul, and Fani, and their impact on rural and economically disadvantaged communities. A particular emphasis is placed on how saline water inundation from these events has affected the lives of these vulnerable populations. This analysis incorporates the socio-economic conditions of the communities and their coping mechanisms, defined as the strategies employed to manage crises (Armah et al., 2010). The study area is located in the southern region of West Bengal and spans 4,151.64 km^2 (Mondal, 2012), positioned between latitudes 21°38' N and 22°31' N and longitudes 87°27' E and 88°12' E (Mondal, 2012). It is bordered by the Bay of Bengal to the south and features the Ghatal Subdivision of the West Medinipur District to the north, the Hooghly River to the east, and the West Medinipur District to the west (Mondal, 2012). The region consists of four subdivisions: Contai, Haldia, Tamluk, and

Egra (Mondal, 2012). Characterized by dune formations, the area also contains fluvial and aeolian sediments, with various tidal channels such as Sankarpur Khal, Jalda Khal, and Ramnagar Khal dividing it (Mondal et al., 2013).

Due to its geographic location and climatic conditions, Ramnagar 1 and 2 blocks are prone to cyclones and erosion from tidal forces, impacting the local economy and environment. The climate has supported Digha-Sankarpur's development as a popular summer resort, with average temperatures from March to June around 30°C and winter temperatures dropping to about 20°C from November to February. Although the monsoon often brings depressions, severe cyclonic storms occur approximately every five to ten years in this coastal region. These high-impact storms typically originate in the Bay of Bengal and can occur during the monsoon, pre-monsoon, and post-monsoon periods. The area faces significant agricultural challenges due to salinity in soil and water, which is worsened by climate-related disasters such as storm surges and cyclones (Sadik et al., 2018). Cyclonic events like Yash, Amphan, Fani, and Bulbul led to significant breaches in embankments, resulting in saline water intrusion into agricultural and aquaculture areas, prolonged waterlogging, soil salinization, and subsequent crop failures (Sally et al., 2018). Agricultural laborers suffered substantial yield losses, and attempts to cultivate alternative crops have been hindered by persistent waterlogging and land degradation (Ahsan et al., 2019).

Overall, the Purba Medinipur district grapples with various challenges, including underdevelopment, limited agricultural development, high reliance on undeveloped agriculture, and a fragile resource base. With a population of over 5 million (Mondal, 2012) and a density of 1,076 people per km^2 (Census, 2011), the district's flat terrain and high tides contribute to drainage issues, particularly in low-lying areas. The main rivers in this region, including Rupnarayan, Kasai-Haldi, and Keleghai, also play a role in exacerbating flooding and waterlogging due to their fluvio-tidal nature. Consequently, the intrusion of saline water and flooding constitutes a critical concern for local communities (Mondal, 2012).

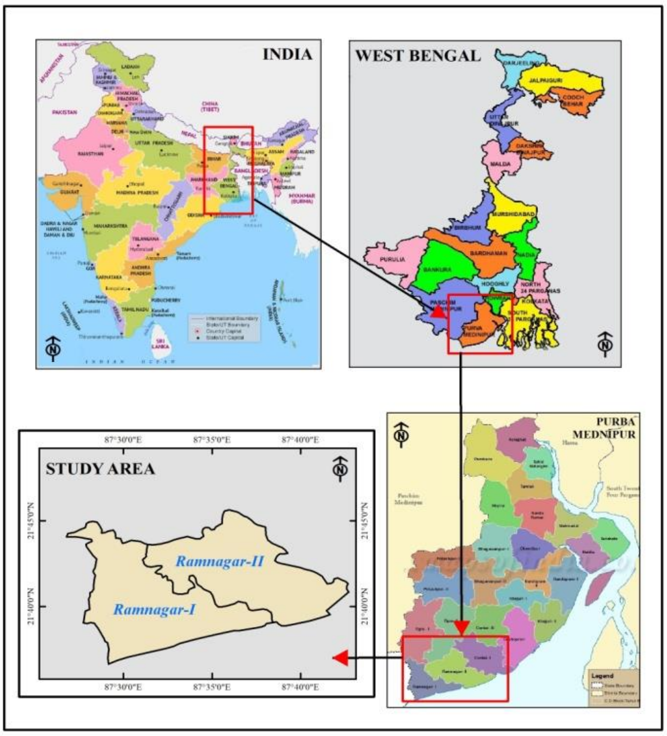


Figure 1. Study area and location map (Source: Maps of India)

2. Method

This study not only observes the impressions of climatic hazard and inundation on the livelihood of the rural coastal dwellers and also analyses their surviving strategies (Parvin;

et. al,2016)). Present research depicted on intensive field investigation. The soil samples were collected from many villages which were harshly affected by earlier inundations caused by climatic hazard. For the household survey, 121 households from two blocks were randomly selected. The senior most member of the households were the respondents, and 75% of them were male within the age of 30 to 65 years.

In count to the designed questionnaire survey, people of different villages with various professions shared their climatic hazard experiences and sufferings. Through this investigation, various types of professional groups were identified, such as agricultural workers, daily labors, businessmen, farmers, servicemen and others. In the time of survey, the conversation with the coastal dwellers, they shared a range of opinions and views and enhanced the data bank of the study (Paul et. Al., 2010). There are 27 soil samples were collected from various points of Block Ramnagar 1 and Ramnagar 2. Collected soil samples were tested in Soil laboratory of River Research Institute, Haringhata, Kolkata. Investigation of several soil properties, their features and quantitative measurement of soil in this area and its surrounding is very essential. Such examinations have been executed for the soil samples, which were collected from the depth of 1 to 1.5 ft.

Mainly Arc GIS 10.8 and Google Earth Pro, Excel 2013 for Graph and charts were used to prepare various maps and diagrams and ERDAS Imagine 9.1 has been used to classify image. Moreover Landsat 8,2013 image is used to detect the land use and land cover changes, (Table 1 and Figure2).

Table 1. Properties of Landsat Image Sources: USGS Earth Explorer OLI: Operational Land Imager; SWIR 1: Short -wave Infrared; NIR: Near Infrared

Sensor	Band number	Band Name	Wavelength (m)	Resolution(m)
OLI	1	Coastal	0.43-0.45	30
OLI	2	Blue	0.45-0.51	30
OLI	3	Green	0.53-0.59	30
OLI	4	Red	0.63-0.67	30
OLI	5	NIR	0.85-0.88	30
OLI	6	SWIR 1	1.57-1.68	30

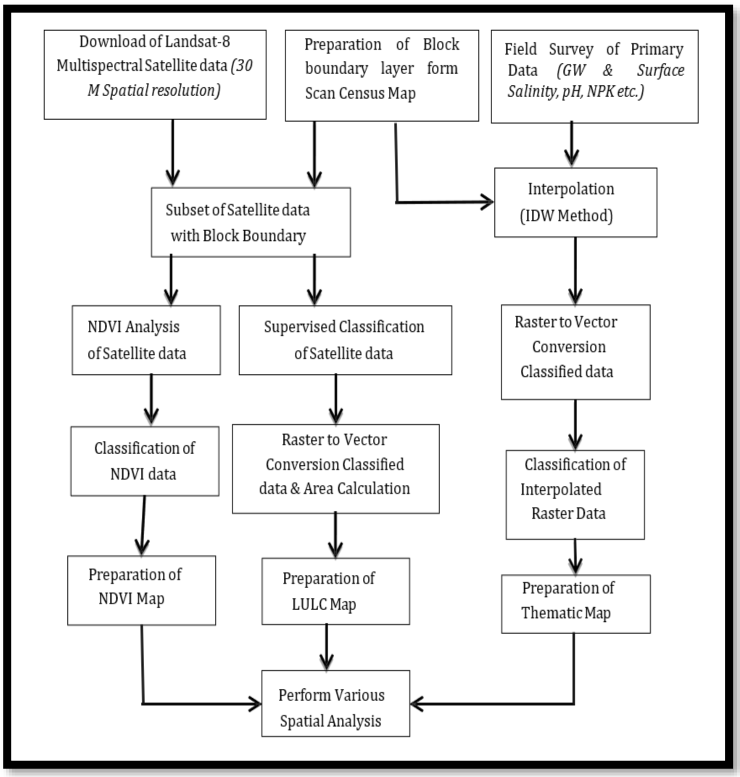


Figure 2. Methodology of preparation of remote sensing and GIS work

3. Results

The changing climate patterns can significantly influence coastal regions in various ways. Coastal areas face risks from alterations in storm frequency and intensity, rising sea levels, increasing ocean temperatures, and variable precipitation (Rhein et al., 2010). These climate variations have already resulted in critical challenges for coastal communities, such as coastal erosion, flooding, and saline water intrusion, alarmingly affecting many regions. Since 1900, global sea levels have risen by approximately 6 to 8 inches (Walsh et al., 2014). The rise in global sea levels has been detected in many coastal areas, leading to further challenges, including increased salinization of agricultural land and groundwater. Excessive salinization can render water undrinkable without desalination and negatively impact agricultural productivity due to inundation from sea tides (Moser et al., 2014).

Additionally, rising sea surface temperatures contribute to the intensity and frequency of cyclones, super cyclones, and precipitation events in coastal areas. Changes in the spatial distribution of precipitation, coupled with temperature variations, greatly heighten the vulnerability of growing populations and development along the coastal region of Purba Medinipur (Sally et al., 2018). Destructive cyclones pose significant natural threats to coastal communities, where 40% to 50% of the rural population resides. These cyclonic events frequently disrupt livelihoods in the coastal region during the monsoon and pre-monsoon seasons. The repercussions include substantial economic losses and heightened societal vulnerability, with widespread devastation to crops and cultivated land due to flooding and super cyclonic storms. Notable events include Super Cyclone Aila in 2009, Super Cyclone Fani and Bulbul in 2019, Super Cyclone Amphan in 2020, and Super Cyclone Yash in 2021, which struck the coasts of the Bay of Bengal and caused extensive damage to southern parts of West Bengal and Bangladesh. These disasters resulted in significant financial losses and massive displacement of people (Halder et al., 2021).

Remote sensing technologies and GIS data provide effective methods for analysing the impact of climatic hazards, such as environmental changes and inundation on a global scale. The availability of satellite data and geospatial technology enables the assessment of environmental degradation or climatic disasters resulting from atmospheric hazards. This study highlights recent climatic hazards related to cyclones, super cyclones, severe super cyclones, and the effects of coastal inundation in West Bengal's coastal areas. Therefore, a thorough study of meteorological hazards is essential for future adaptation, awareness, preparedness, disaster shelters, cyclone shelters, and enhancing personal resilience across the entire coastal region (Halder et al., 2021).

In this study, we examined the changing patterns of land use and land cover (LULC) in the years 2000, 2010, and 2022 for the Ramnagar 1 and 2 blocks (Figures 3a, 3b, 3c). The LULC was developed using standard classification techniques applied to satellite images (Sinha et al., 2013) and area calculations for year-wise LULC classes documented in Table 3. Machine Learning (ML) supervised algorithms produce more accurate results than the conventional techniques for classification of satellite imagery (Sarker 2021). ML-based satellite data classification has been performed globally (Talukdar et al., 2020), however, the selection of appropriate ML algorithm is crucial for attaining the desired accuracy (Maxwell et al., 2018). Henceforth, we have adopted Random Forest (RF) algorithm in this study, which is an ensemble supervised learning method for image classification, after reviewing relevant literatures, including Zafar et al. (2024), Aryal et al. (2023), Arpitha et al. (2023) and Loukika et al. (2021) among many more. Using separate verification samples naturally extracted through random sampling from Google Earth and field data, accuracy of the classified images in terms of the producer's accuracy (PA), user's accuracy (UA), OA (overall accuracy) and k (kappa accuracy) depending on the standard confusion measures utilized were assessed quantitatively (Sinha et al. 2015; 2020), mentioned in Table 2. The OA and k values for all three years were more than 90% and 0.9 respectively, which reveals the efficacy of RF classifier in the area, accepted in the study. Figure 3 displays the satellite derived LULC map layouts for 2000, 2010 and 2022 together with the Table 2 showing the LULC areal changes of various land use groups. The area dedicated to agricultural land in 2000 was 28.848 km^2; this increased to 48.098 km^2 in 2010 but then decreased to 18.099 km2 in 2022. The area of fallow land expanded from 45.649 km2 in 2000 to 66.935 km^2 in 2010, before declining to 13.931 km2 in 2022. Vegetation area decreased from 82.054 km^2 in 2000 to 66.935 km2 in 2010 but increased significantly to 181.247 km^2 by 2022. The area covered by water bodies was approximately 10.279 km2 in 2000, reduced to 9.95 km^2 in 2010, and increased to 17.035 km^2 in 2022. Settlements expanded from 57.588 km^2 in 2000 to 114.666 km^2 in 2010, but then decreased to 71.503 km^2 in 2022. Overall, land use and land cover patterns have changed from 2000 to 2022, with increased areas of vegetation, water bodies, and settlements, particularly the significant rise in water bodies attributed to storm surge flooding and the effects of prolonged waterlogging.

Table 2. Accuracy assessment report

	2000		2010		2022	
LULC	**UA**	**PA**	**UA**	**PA**	**UA**	**PA**
water	95.65	100.00	94.12	94.12	96.55	100.00
settlement	92.65	90.00	92.47	89.58	95.65	91.67
agricultural land	92.00	93.88	87.10	96.43	86.96	95.24
vegetation	93.68	94.68	93.44	89.06	98.90	98.35
fallow land	95.31	93.85	94.03	94.03	90.48	90.48
OA	93.67		92.00		96.67	
k	0.92		0.90		0.94	

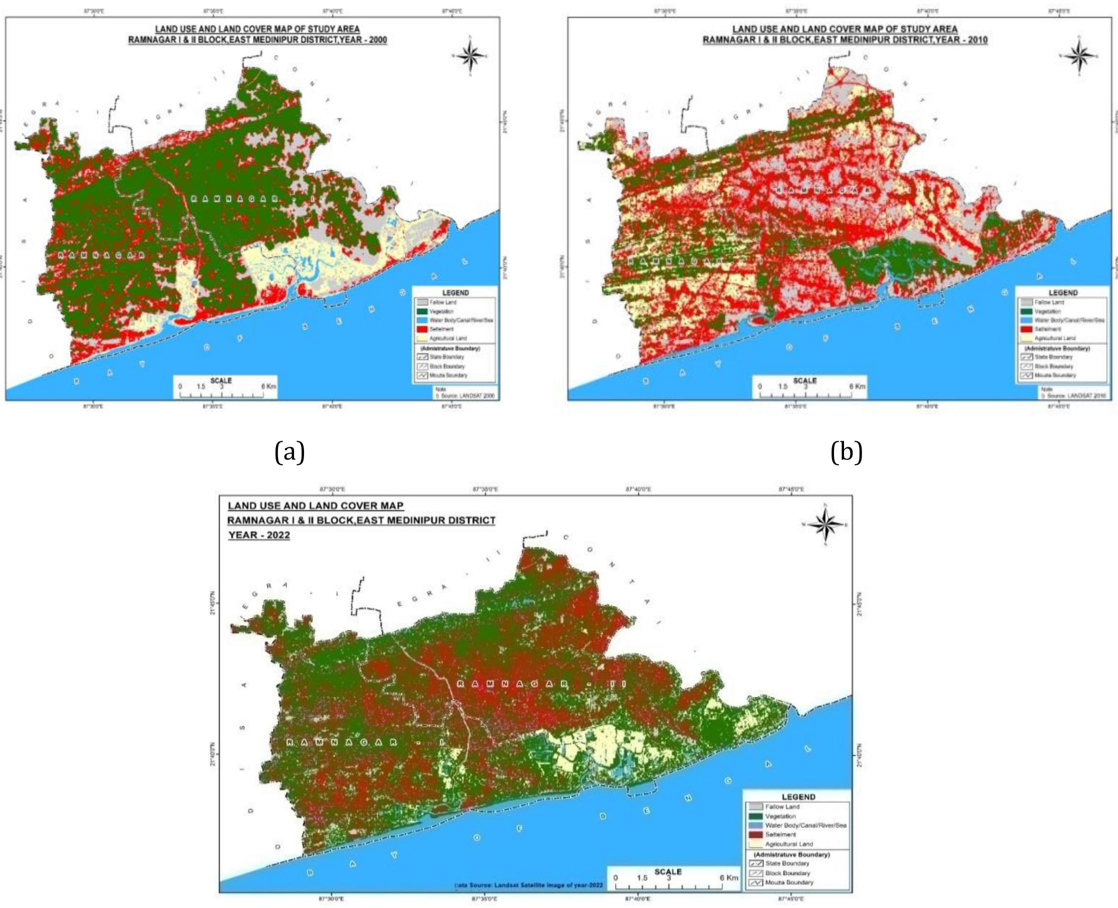
According to satellite image analysis, significant changes in land use and land cover have occurred over the past 22 years, primarily driven by climate change, environmental factors, afforestation, and frequent climatic hazards. These climatic events have severely impacted agricultural land, potentially altering land use patterns (Iban, 2020). The peninsular shape of the Indian subcontinent acts as a pathway for cyclonic disturbances originating from adjacent seas. A concerning consequence of global warming and increasing sea temperatures is the likely intensification of extreme climatic events, including cyclones and storms (Nandargi et al., 2019).

This study examines the frequency and concentration of tropical disturbances from 1970 to the present, with a particular focus on the past five years, to understand their impacts on coastal zones. The presence of these disturbances over the seas is closely linked to heavy rainfall patterns and storm surge flooding in low-lying coastal areas. According to data from the India Meteorological Department (IMD) (supplementary Table 1), various types of cyclones, including severe and extremely severe cyclones, have been recorded every decade since 1970, resulting in significant fatalities and damage. The frequency and intensity of these climatic events are increasing; for example, there was one extremely severe cyclone from 1970 to 1980, four severe cyclones each in the 1980s and 1990s, and five and eight disturbances recorded from 2000 to 2010 and 2010 to 2024, respectively. The recurring occurrence of cyclones poses a deadly natural hazard to the coastal populations in West Bengal over the last five to ten years.

IMD data and information from the River Research Institute (supplementary Table 2) indicate that the wind speeds of Cyclones Fani (2019), Bulbul (2019), Amphan (2020), and Yash (2021) were 180 km/h, 48 km/h, 120 km/h, and 150 km/h, respectively. These wind speeds contribute to storm surge flooding during high tides, with water levels reaching 5.915 m during Cyclone Fani, 3.70 m during Cyclone Bulbul, 4.945 m during Cyclone Amphan, and 7.2 m during Cyclone Yash, inundating low-lying areas of the coast. Storm surge flooding is a common occurrence in this region, leading to significant loss of life and property, with lasting impacts. Field surveys indicate that tidal and storm surges have increased soil and water salinity (Rahman et al., 2017), rendering ponds and tube wells polluted by saline floodwaters.

This situation greatly affects coastal households, as these water sources are vital for daily use. Villagers report that agricultural fields become saline due to storm surge flooding during climatic events, making cultivation impossible for the following 3 to 5 years.

Satellite imagery clearly shows that the agricultural land area decreased from 48.098 km^2 in 2010 to 18.099 km^2 in 2022. The 2011 census recorded a total cultivated area of 12,932.94 hectares in Ramnagar 1 and 15,840.42 hectares in Ramnagar 2; however, social surveys indicate that 60% to 70% of the cultivated land has turned saline following the incidents of Cyclones Yash, Amphan, and other climatic hazards. The high sea surface temperature in the Bay of Bengal makes it more prone to cyclones than the Arabian Sea. The sea surface temperature, humidity, and kinetic energy are crucial factors in cyclone formation (Nandargi et al., 2019). In time series analysis of Year wise average temperature (From year 1983 to 2023) of Purba Medinipore (Figure 4a) is depicting gradual increasing of temperature in last 40 years and Time series of average rainfall (Figure 4b) gradually decreasing in last 40 to 50 years (from 1970 to 2023). The Bay of Bengal experiences high average temperature and uncertainty of rainfall, which increases the likelihood of cyclone formation, thanks to the substantial moisture present in the atmosphere's mid-layers. Additionally, the peninsula shape of India (Nandargi et al., 2019) contributes to the increased occurrence of cyclones. The warm waters of the ocean create vast low-pressure systems that facilitate cyclone formation in the Bay of Bengal. The trough-like shape of the bay allows storms to gain energy as they spiral. Meteorologists believe that severe cyclones form when strong winds push water into the bay's curved, shallow zones, triggering storms. The lack of landmass between the Bay of Bengal and the coast propels cyclonic winds toward coastal areas. Over the past decade, the eastern coastal region has been devastated by at least eight severe super cyclones, with significant landfalls occurring in the coastal regions of Odisha, West Bengal, Bangladesh, and Andhra Pradesh.



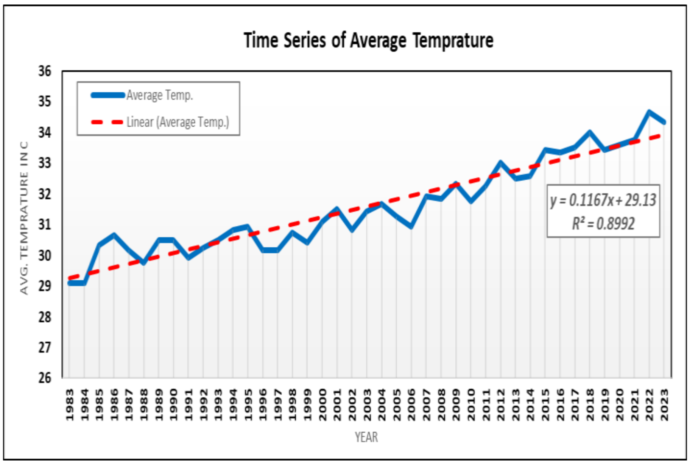
(a) (b)

(c)

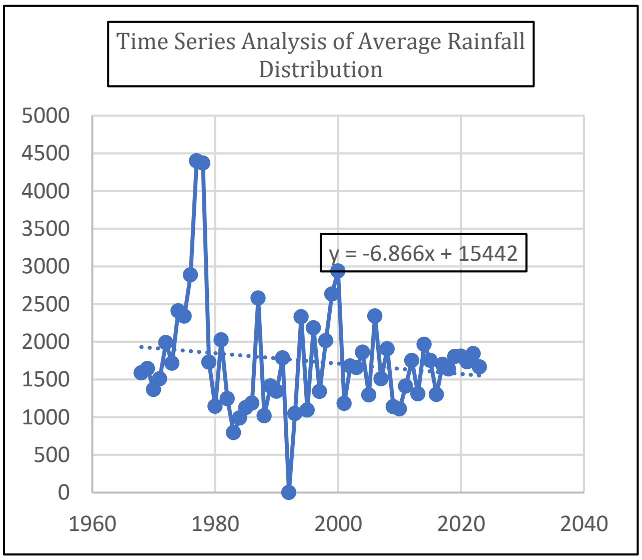
Figure 3. (a) Land use & land cover map-2000, (b) land use & land cover map-2010, (c) land use & land cover map-2022

Table 3. Land use and land cover changes in the year (2000-2010-2022)

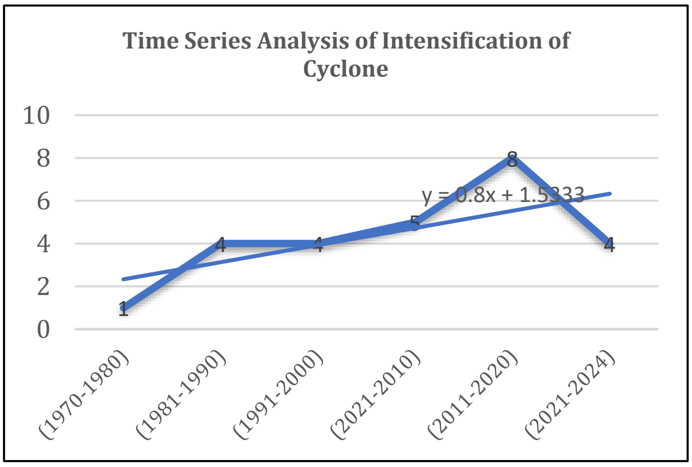
Class name	Area (Km^2) (2000)	Area (Km^2) (2010)	Area (Km^2) (2022)
Agriculture	28.848	48.093	18.099
Dry Fallow land	45.649	82.386	13.931
Vegetation	82.054	66.935	181.247
River/Water body/canal	10.279	9.95	17.035
Settlement	57.588	114.666	71.503



(a)



(b)



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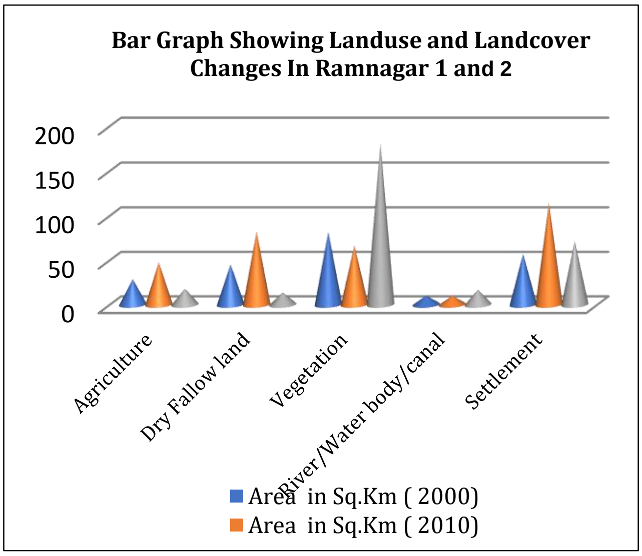


(d)

Figure 4. (a) Gradual increasing of temperature (1983 to 2023), (b) gradual decreasing of rainfall (1965 to 2023), (c) intensification of cyclones (1970-2024), (d) land use and land cover changes from the year2000 to 2022

Table 4. Numbers of cyclones (1970 to 2024)

Year	Nos. of Cyclones
(1970-1980)	1
(1981-1990)	4
(1991-2000)	4
(2021-2010)	5
(2011-2020)	8
(2021-2024)	4

4. Discussions

Coastal communities heavily rely on natural resources for their livelihoods, predominantly engaging in agriculture and fishing. However, these sectors have been severely impacted by cyclones and other climatic hazards (Rahman et al., 2019). This study indicates that, over the past 5 to 10 years, the agricultural lands in the southern parts of the coastal regions have become unproductive due to the accumulation of saline water from sea water intrusion (Habiba et al.,2014) during cyclonic storms. Consequently, the occurrence of these climatic hazards has altered land use patterns, resulting in a decrease in average land size in the study areas of Block Ramnagar 1 and Ramnagar 2. The agricultural lands are under threat of disappearing, imposing significant financial burdens on farmers. It has been noted that a decline in the soil quality of agricultural land has adversely affected crop production, potentially leading to shifts in livelihood (Gray et al., 2011). Figures 5a and 5b presented in this chapter illustrate the relationship between soil salinity and soil pH, which are interconnected with agricultural systems. The soil salinity map indicates that areas within 2 km of the coastline are highly affected by salinity (greater than 3 ds/m), while the 2 to 6 km range shows elevated salinity levels (2-3 ds/m). In contrast, areas beyond 6 km from the coastline experience low to very low salinity. According to the 2011 census, the total area of Ramnagar 1 is 139.43 km^2, and Ramnagar 2 is 163.27 km^2; agricultural data from the agricultural department suggests that approximately 60 to 65 km^2 of each block has been impacted by salinity due to climatic hazards on multiple occasions.

Soil pH (Alptekin et al 2019) is also a crucial factor in agricultural fertility. As noted by Bruckner (2012), a lower soil pH indicates a higher concentration of hydrogen ions. An accumulation of these ions can alter electrical conductivity (related to soil salinity). Soils rich in hydrogen ions exhibit higher electrical conductivity rates. The soil pH map shows that the majority of this area has pH levels below 7 or between 7 and 8, with values below 7 indicating increased acidity. High electrical conductivity and acidic conditions hinder agricultural productivity. Following the impacts of Cyclones Amphan and Yash, soil salinization has contributed to diminished agricultural yields. Field surveys reveal that some farmers have attempted to mitigate salinity by using lime, tamarind, and rotten mango leaves, while others are growing salt-tolerant crops such as brinjal, chili, cauliflower, cabbage, rape seed, and mustard greens (Wang et al., 2010; Kim et al., 2016).

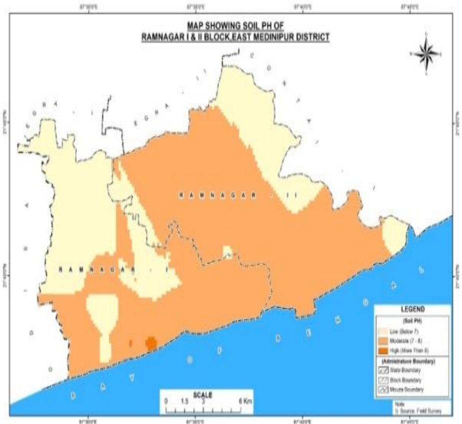
For this study, it is crucial to analyses the agricultural landscape of this coastal region from 2000 to 2022 using GIS and remote sensing techniques. The Normalized Difference Vegetation Index (NDVI) is a scientific method employed to assess the health, density, yield of vegetation, and crops. Formula of NDVI is (NIR - R) / (NIR + R) as mentioned in Sinha et al. (2015). High salt concentration and acidic soils negatively influence agricultural productivity, primarily due to water scarcity caused by salinity, which reduces plants' ability to absorb water and subsequently affects their nutritional intake. NDVI values range from -0.1 to 1; negative values indicate water or cloud cover, values close to zero represent bare land, and higher values (0.6 to 1.0) indicate healthy, dense vegetation. Remote sensing techniques utilizing NDVI help evaluate various parameters, including cultivated areas, crop productivity, and plant nutrition. The NDVI values for cultivated agricultural land range from 0.6 to 0.7, reflecting dense, healthy vegetation and robust crop growth. NDVI maps from the years 2000 (Figure 6a), 2010 (Figure 6b), 2015 (Figure 6c), and 2022 (Figure 6d) show values from -0.54 to +0.7, -0.239 to +0.55, -0.16 to +0.57, and -0.16 to +0.51, respectively, illustrating a gradual decrease in vegetation index associated with agricultural productivity from 2000 to 2022. The most significant changes in NDVI values are observed from the coastline to 25 to 30 km inland, where soil salinity has severely affected the land. Mainly increasing of Soil salinity and alkalinity of soil have become significant threats to agricultural productivity in these coastal areas (Fig no:6d,6e). This paper highlights the impact of soil salinity and soil pH can lead to reduce crop growth, lower yield and decreased quality of productivity.

There is a relationship between gradual climate change, the formation of cyclones (last 50 years,) in the Bay of Bengal, and their impact on coastal areas. the gradual climate change, characterized by rising temperatures (Time series analysis of Temperature: Figure 4a) and decreasing rainfall (Time series analysis of Rainfall: Figure 4b), has contributed to an increase in cyclone frequency (Time series analysis of intensification of Cyclones: Figure 4c) and intensity in the Bay of Bengal (Nandargi, et.al 1998). This, in turn, has exacerbated the impact of cyclones on coastal areas, highlighting the need for climate-resilient infrastructure, early warning systems, and adaptive management strategies to mitigate the effects of climate change. The Bay of Bengal has experienced a significant increase in Sea Surface Temperature over the last few decades, which is a key factor in the formation and intensification of cyclones and warmer oceans evaporate more moisture into the atmosphere, leading to increased humidity and instability in the atmosphere, conducive to cyclone formation (Subhani et.al., 2019). Cyclones bring storm surges that can inundate coastal areas, causing damage to infrastructure, agriculture, and human settlements. Cyclones can lead to coastal erosion, sedimentation, and changes in coastal morphology, affecting coastal ecosystems and human livelihoods.

The climatic hazards have significantly impacted the social dynamics and economic conditions of coastal communities in various ways, including property damage, food shortages, and limited access to water. Vulnerable populations, in particular, often lack the resources to effectively cope with the socioeconomic challenges posed by natural disasters (Mallick et al., 2011). The effects of these climatic events extend beyond immediate loss of life or property; their long-term consequences disrupt the socioeconomic scenario of coastal communities. As a result, this community often require to recover their lost income, leading to a shift in livelihoods.

Changing occupational patterns become common among those affected by natural calamities as they adapt to new environmental conditions. When primary income sources fail to meet basic needs, people commonly explore alternative income-generating opportunities. Data from social surveys (Table 5a,5b, Figures 7a to 7c) reveal that prior to the climatic hazards, 68 households (53.33%) depended on agriculture, 11 households (9.34%) employed in services, 18 households (13.7%) engaged in daily labor across various sectors,17 households (13.7%) engaged in various business and 13 households (9.86%) pursued other forms of work. However, following the climatic hazards and the subsequent decrease in agricultural productivity, the 39 (31.33%) number of households involved in various food processing businesses near Digha Sankarpur Sea Beach. Additionally, around 19 households (15.24%) found employment in the hotel industry, 15 households (11.70%) entered the transportation sector, 24 households (18.60%) engaged in making handicrafts from seashells, and 10 households (8.3%) ventured into other businesses, while 7 households (6.1%) were left jobless. Consequently, coastal residents face increasing financial challenges after each climatic disaster. The government relief funds have proven inadequate to address these adverse situations. Social survey data (Table 3 and Figures 7a to 7d) indicate that, before the climatic hazards, out of 127 households, 11 (4.7%) reported a monthly income exceeding twenty thousand, 62 (27.32%) earned between fifteen and twenty thousand, 67 (29.41%) received between ten and fifteen thousand, and 76 households (33.39%) earned between five and ten thousand monthly. A very small percentage of households had incomes below five thousand. However, rural residents have faced significant hardship due to the recurring effects of climatic hazards and the COVID-19 pandemic. The financial crisis has become a persistent issue for coastal villagers. Current data show that only 2% of households earn more than twenty thousand monthly, while 43.07% earn between five and ten thousand, and 21.44% earn between ten and fifteen thousand. This chapter illustrates that the socioeconomic conditions of the coastal populations in Block Ramnagar 1 and Ramnagar 2 are dire due to natural disasters. The loss of agricultural land further threatens farmers' livelihoods, significantly impacting their quality of life (Gray, 2011).

For analysis of this study, it is observed negative slope, in statistical analysis in Figure 6d that, soil salinity increases, agricultural productivity decreases (value is Y=-2.45X+18.147). It is also observed negative slope in Figure 6e, that as soil pH increases then agricultural productivity decreases (value is Y=-0.0895X+8.0703). It is proved that high concentration of sodium chloride and excessive alkalinity can lead to osmotic stress and ion toxify, nutrient deficiency so this process inhibits the plant root growth and seed germination.



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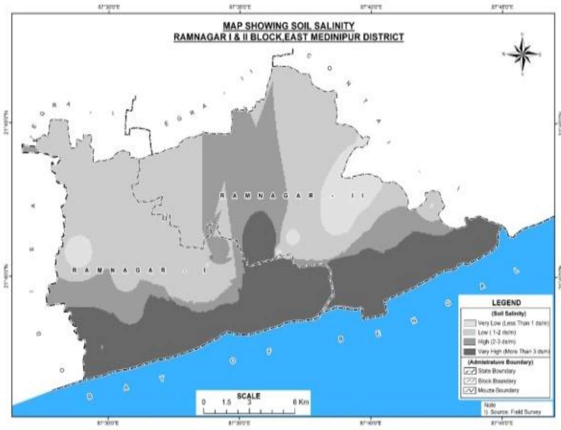
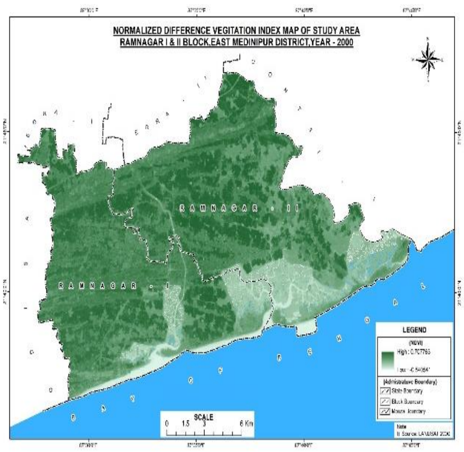


(b)

Figure 5. (a) Soil salinity map, (b) soil pH map



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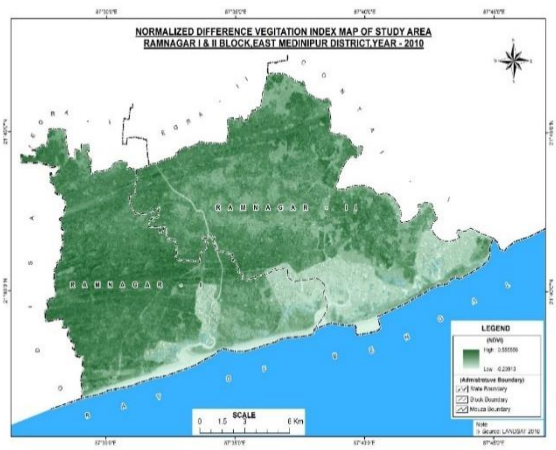

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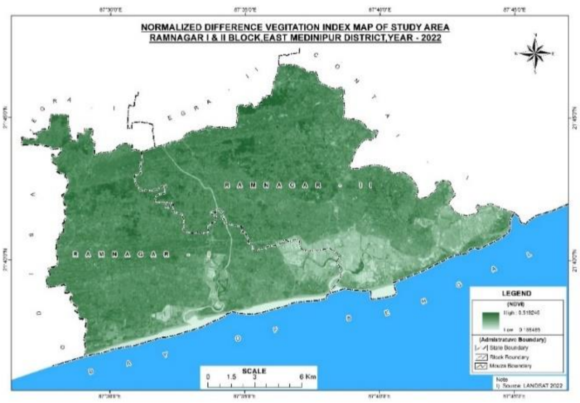

(c)

Figure 6. (a) NDVI,2000, (b) NDVI,2010, (c) NDVI, 2022

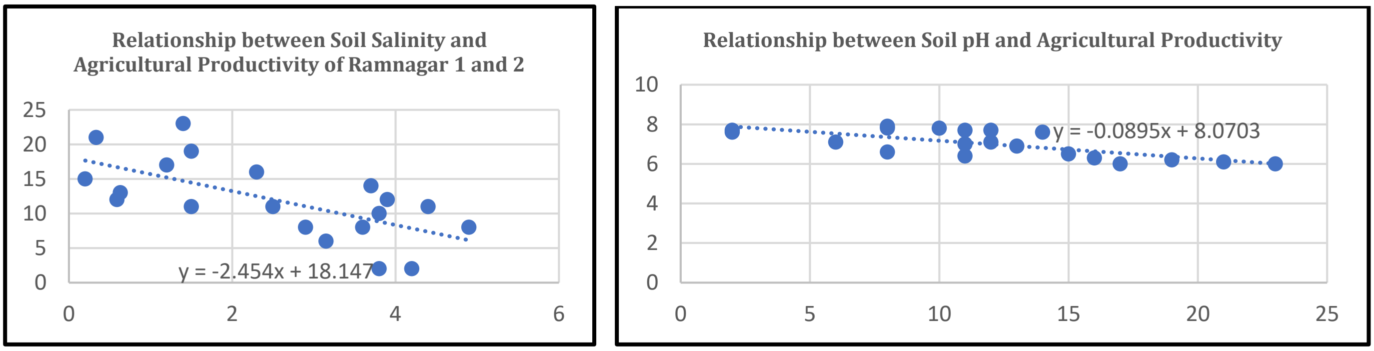

Figure 7. (a) Scatter diagram (Source: Field survey and Social Survey), (b) scatter diagram (Source: Field survey and Social Survey)

Table 6. Occupation Pattern of Coastal Dwellers Before Climatic Hazard (Ramnagar1 and 2) (Source: House Hold survey)

Occupation Pattern	% of Coastal Dwellers before Climatic Hazard
Agriculture	53.33
Service	9.34
Business	13.7
Daily Labor	13.8
other	9.86

Table 7. Occupation Pattern of Coastal Dwellers After Climatic Hazard (Ramnagar1 and 2)

Occupation Pattern	%of Coastal Dwellers after climatic Hazard
Food Shop near Sea Beach	31.33
Labor in Hotel Industry	15.24
Transport business	11.7
Hand Craft making	18.6
Business	8.3
Jobless	6.1
Service	8.73

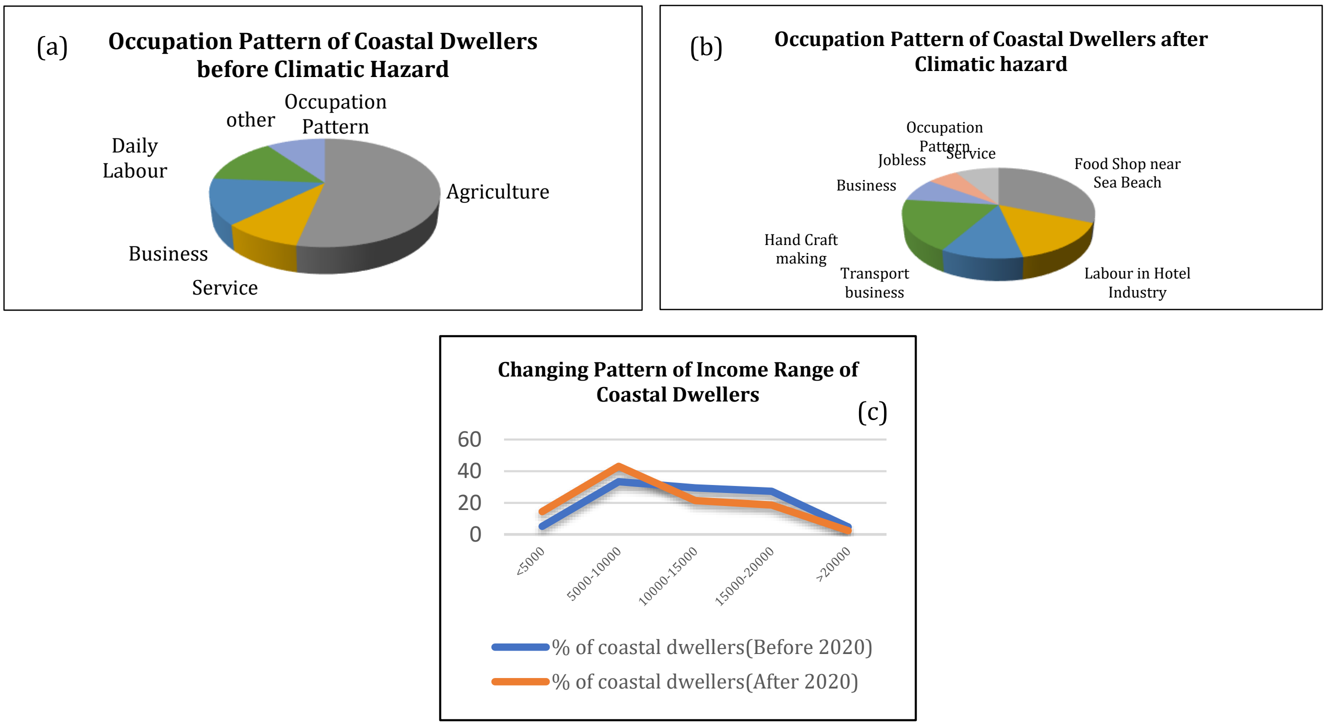

Figure 8. (a) Occupation pattern of coastal dwellers before climatic hazard, (b) occupation pattern of coastal dwellers after climatic hazard, (c) changing pattern of income range (before 2020 and after 2020)

Table 8. Changing pattern of Income Range (Before 2020 and After 2020) (Source: House Hold survey)

Income range before Climatic Hazard (in Rupees)	% Of House Hold	Income range After Climatic Hazard (In Rupees)	% Of House Hold
<5000	5.12	<5000	14.42
5000-10000	33.39	5000-10000	43.07
10000-15000	29.41	10000-15000	21.44
15000-20000	27.32	15000-20000	18.59
>20000	4.7	>20000	2.46

5. Conclusion

This study examines the impact of climatic hazards, particularly cyclones and super cyclones, on the rural coastal population in the Ramnagar 1 and 2 blocks of Purba Medinipur, West Bengal. Recent findings indicate that these climatic events significantly disrupt agricultural lands, income, food consumption, employment, and housing for local communities (Subhani et al., 2019). The destruction wrought by cyclones and storm surge floods presents formidable challenges to the economic stability of coastal villagers, who face property damage, transportation disruptions, and threats to their health and safety. Consequently, many residents are forced to migrate in search of better opportunities (Karl et al., 2009). Rising sea levels exacerbate the intensity of storms by increasing the baseline from which storm surges occur (NRC, 2010). Major climatic events, particularly super cyclones like Amphan and Yash, have devastated livelihoods and properties. Many coastal residents were unable to protect their valuables and crucial documents during these disasters. The impact of these cyclones, coupled with high tides and storm surges, resulted in extensive flooding, further complicating recovery efforts (Wong et al., 2014). While some individuals managed to evacuate, they often did not have adequate time to save livestock or preserve their cultivated fields and gardens, which were inundated with saline seawater following river embankment breaches. As a result, numerous families relied on dry food donations from NGOs and social organizations for sustenance in the aftermath. The necessity for comprehensive disaster and hazard management (CIRDAP, 1991) studies becomes evident as communities strive to adapt to these challenges, stressing the need for increased alertness, awareness, and the establishment of cyclone shelters and relief camps (Subhani et al., 2019). The impact of climate change on the livelihoods of marginalized communities in Purba Medinipur is profound, significantly altering the socio-economic landscape of these vulnerable populations. The evidence indicates that livelihoods reliant on agriculture and fishing have been severely disrupted, resulting in economic instability and growing poverty. Saline intrusion and shifting weather patterns have degraded agricultural land, leading to substantial declines in crop productivity. This reality forces many individuals to pursue alternative sources of income, which often leads to precarious and unsustainable livelihoods. The transition away from traditional agricultural practices not only undermines economic stability but also threatens the loss of traditional knowledge and cultural practices that have historically sustained these communities. Furthermore, inadequate governmental responses and relief measures exacerbate the hardships faced by coastal residents. The financial assistance provided has proven insufficient in meeting the challenges posed by frequent climatic disruptions, impeding recovery efforts and enforcing a continuous state of vulnerability. The findings highlight an urgent need for comprehensive policy interventions that address both immediate relief and long-term resilience-building strategies. In light of these challenges, prioritizing climate adaptation initiatives tailored to the specific needs of marginalized communities in Purba Medinipur is critical. This includes enhancing disaster preparedness, improving access to alternative livelihood opportunities, and investing in sustainable agricultural practices. Empowering local communities through education, resources, and support systems is essential in fostering resilience against future climatic hazards. In conclusion, the struggles faced by marginalized coastal dwellers in Purba Medinipur underscore the urgent need for collective action to confront the effects of climate change. By acknowledging the interconnectedness of environmental, social, and economic factors, stakeholders—including government entities, NGOs, and the communities themselves—can collaboratively create a more equitable and sustainable future for these vulnerable populations.

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Author Contributions:
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G. Bhandari: Conceptualization, Methodology, Validation, Resources, Writing—review and editing, Supervision
S. Sinha: Methodology, Software, Validation, Formal analysis, Investigation, Writing—review and editing, Visualization, Supervision

Research and publication ethics statement: In the study, the authors declare that there is no violation of research and publication ethics and that the study does not require ethics committee approval.

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References

Ahsan, R. (2019) Climate induced migration: impacts on social structure and justice in Bangladesh. *The International Journal of Climate Change: Impacts and Responses,* 39(2), 184-201. https://doi.org/10.1177/0262728019842968

Aleem, M., Ahmed, S. A., & H, N. (2023). Land use and land cover classification using machine learning algorithms in google earth engine. *Earth Science Informatics*, 16, 3057–3073. https://doi.org/10.1007/s12145-023-01073-w

Alptekin, A. & Taga, H. (2019). Prediction of compression and swelling index parameters of Quaternary sediments from index tests at Mersin district. *Open Geosciences*, 11(1), 482-491. https://doi.org/10.1515/geo-2019-0038

Armah, F. A., Yawson, D. O., Yengoh, G. T., Odoi, J. O., & Afrifa, E.K.A. (2010) Impact of floods on livelihoods and vulnerability of natural resource dependent communities in Northern Ghana. *Water*, 2, 120–139. https://doi.org/10.3390/w2020120

Arpitha, M., Ahmed, S. A., & Harishnaika, N. (2023). Land use and land cover classification using machine learning algorithms in google earth engine. *Earth Science Informatics,* 16, 3057–3073. https://doi.org/10.1007/s12145-023-01073-w

Aryal, J., Sitaula, C., & Frery, A. C. (2023). Land use and land cover (LULC) performance modeling using machine learning algorithms: A case study of the city of Melbourne, Australia. *Scientific Reports*, 13, 1351. https://doi.org/10.1038/s41598-023-40564-0

Barros, D. J., Dokken, K. J., Mach, M. D., Mastrandrea, T. E., Bilir, M., Chatterjee, K. L., Ebi, Y. O., Estrada, R. C., Genova, B., Girma, E. S., Kissel, A. N., Levy, S., MacCracken, P. R., Mastrandrea,, & White, L. L. (2014). Climate change 2014: Impact, adaptation and vernability. Cambridge University Press.

Billa, L., Shattri, M., Mahmud, A.R., & Ghazali, A.H. (2006) Comprehensive planning and the role of SDSS in flood disaster management in Malaysia. *Disaster Prevention Management An International Journal* 15(2), 233–240. https://doi.org/10.1108/09653560610659775

Brouwer, R., Akter, S., Brander, L., & Haque, E. (2007). Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. *Risk Analysis: An International Journal*, 27(2), 313-326. https://doi.org/10.1111/j.1539-6924.2007.00884.x

Bruckner, M.Z. (2012) Water and soil characterization- pH and electrical conductivity. Microbial Life Educational Resources. Montana State University Bozeman.

Cash, R. A., Halder, S. R., Husain, M., Islam, M. S., Mallick, F. H., May, M. A., Rahman, M., & Rahman, M. A. (2013). Reducing the health effect of natural hazards in Bangladesh. *The Lancet*, 382(9910), 2094-2103. http://dx.doi.org/10.1016/S0140-6736(13)61948-0

CIRDAP. (1991). Center on Integrated Rural Development for Asia and the Pacific (CIRDAP). Development of modules for training on integrated approach to rural development and disaster management in Bangladesh, Final Report of UNCRD-CIRDAP.

Gray, C. L. (2011). Soil quality and human migration in Kenya and Uganda. *Global Environmental Change*, 21(2), 421-430. https://doi.org/10.1016/j.gloenvcha.2011.02.004

Habiba, U., Abedin, M. A., Shaw, R., & Hassan, A. W. R. (2014). Salinity-induced livelihood stress in coastal region of Bangladesh. In water insecurity: A social dilemma. Emerald Group Publishing Limited.

Halder, B.; Das, S.; Bandyopadhyay, J.; Banik,P.(2021) The deadliest tropical cyclone 'Amphan': investigate the natural flood inundation over south 24 Parganas using google earth engine. Springer Nature. https://doi.org/10.1007/s42797-021-00035-z

Huang, X., Tan, H., Zhou, J., Yang, T., Benjamin, A., Wen, S. W., Li, S., Li, X., Fen, S., & Li, X. (2008). Flood hazard in Hunan province of China: an economic loss analysis. *Natural Hazards*, 47, 65-73. https://doi.org/10.1007/s11069-007-9197-z

Iban, M. C. (2020). Geospatial data science response to COVID-19 crisis and pandemic isolation tracking. *Turkish Journal of Geosciences*, 1(1), 1-7.

Johnson, J. D. (2006) Natural disaster and vulnerability; OECD development center policy Brief No. 29. OECD Development Center: Berlin, Germany. https://doi.org/10.1787/202670544086

Karl, T. R., Melillo, J. M., & Peterson. T.C. (2009). USGCRP global climate change impacts in the United States, coasts United States Global Change Research Program. Cambridge University Press.

Lavender, S. L., Hoeke, R. K., & Abbs, D. J. (2018). The influence of sea surface temperature on the intensity and associated storm surge of tropical cyclone Yasi: a sensitivity study. Natural Hazards and Earth System Sciences, 18(3), 795-805. https://doi.org/10.5194/nhess-18-795-2018

Loukika, K. N., Keesara, V. R., & Sridhar, V. (2021). Analysis of land use and land cover using machine learning algorithms on Google Earth Engine for Munneru River Basin, India. *Sustainability*, 13, 13758. https://doi.org/10.3390/su132413758

Mahadevia, K., & Vikas, M. (2012). Climate change–impact on the Sundarbans, a case study. *International Scientific Journal: Environmental Science*, 2(1), 7-15.

Mallick, B., Rahaman, K. R., & Vogt, J. (2011). Coastal livelihood and physical infrastructure in Bangladesh after cyclone Aila. *Mitigation and adaptation strategies for global change*, 16, 629-648. https://doi.org/10.1007/s11027-011-9285-y

Maxwell, A. E., Warner, T. A., & Fang, F. (2018). Implementation of machine-learning classification in remote sensing: An applied review. *International Journal of Remote Sensing,* 39(9), 2784–2817. https://doi.org/10.1080/01431161.2018.1433343

Messner, F., & Meyer, V. (2006) Flood damage, vulnerability and risk perception-challenges for flood damage research. Springer.

Mondal, M. (2012) Land people - a dynamic interaction of Purba Medinipur district, West Benga. *IOSR Journal of Pharmacy* 2(6), 56-61. https://doi.org/10.9790/3013-26405661

Mondal, M., Dandapath, P. K., & Shukla, J. (2013). Mapping Dynamics of land utilization and its changing Patterns of Purba Medinipure District-WB. *International Journal of Innovative Research and Development*, 2(1), 664-676.

Moser, S. C., Davidson, M. A., Kirshen, P., Mulvaney, P., Murley, J. F., Neumann, J. E., Petes, L., & Reed, D. (2014). Ch. 25: coastal zone development and ecosystems. Climate Change Impacts in the United States: The Third National Climate Assessment, JM Melillo, Terese (TC) Richmond, and GW Yohe, Eds., US Global Change Research Program, 579-618.

Nandargi, S. S., & Mahto, S. S. (2019). Frequency and intensity of tropical disturbances over the Indian region and its neighboring seas with associated rainfall during the monsoon season: A perspective. *Engineering Reports*, 1(5), e12069. https://doi.org/10.1002/eng2.12069

Nandargi, S., & Dhar, O. N. (1998). An appraisal of successive tropical disturbances and their associated severe rainstorms during monsoon months. *Journal of Meteorology*, 23(231), 221-228.

NRC. (2010). National Research Council (NRC). Adapting to the Impacts of Climate Change. (NRC). The National Academies Press.

Parvin, G. A., & Shaw, R. (2013). Microfinance institutions and a coastal community's disaster risk reduction, response, and recovery process: a case study of Hatiya, Bangladesh. *Disasters*, 37(1), 165-184. https://doi.org/10.1111/j.1467-7717.2012.01292.x

Parvin, G. A., Shimi, A. C., Shaw, R., & Biswas, C. (2016). Flood in a changing climate: The impact on livelihood and how the rural poor cope in Bangladesh. *Climate*, 4(4), 60. https://doi.org/10.3390/cli4040060

Paul, S. K., & Routray, J. K. (2010). Flood proneness and coping strategies: the experiences of two villages in Bangladesh. *Disasters*, 34(2), 489-508. https://doi.org/10.1111/j.1467-7717.2009.01139.x

Rahman, S., Rahman, H., Shahid, S., Khan, R. U., Jahan, N., Ahmed, Z. U., ... & Mohsenipour, M. (2017). The impact of cyclone Aila on the Sundarban forest ecosystem. *International Journal of Ecology and Development*, 32(1), 87-97.

Rahman, S., Rahman, H., Shahid, S., Khan, R. U., Jahan, N., Ahmed, Z. U., Khanum, R., Ahmed, M. F., Ahsan, R., Kellett, J., Karuppannan, S. (2014). Responses to drought and desertification in the Moroccan Drâa Valley Region: Resilience at the expense of sustainability? *The International Journal of Climate Change: Impacts and Responses*, 5(2), 17.

Rayhan, M. I. (2010). Assessing poverty, risk and vulnerability: a study on flooded households in rural Bangladesh. *Journal of Flood Risk Management,* 3(1), 18-24. https://doi.org/10.1111/j.1753-318X.2009.01051.x

Rhein, M., Rintoul, S. R., Aoki, S., Campos, E., Chambers, D., Feely, R. A., Gulev, S., Johnson, G. C., Josey, S. A., Kostianoy, A., Mauritzen, C., Roemmich, D., Talley, L. D., & Wang, F. (2013) Observations: Ocean In Climate Change 2013 IPCC: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ,Cambridge University Press.

Sadik, M. S., Nakagawa, H., Rahman, M. R., Shaw, R., Kawaike, K., Parvin, G. A., & Fujita, K. (2018). Humanitarian aid driven recovery of housing after Cyclone Aila in Koyra, Bangladesh: Characterization and assessment of outcome. *Journal of Japan Society for Natural Disaster Science*, 37(S05), 73-91. https://doi.org/10.24762/jndsj.37.S05_73

Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science*, 2, 160. https://doi.org/10.1007/s42979-021-00592-x

Sinha, S., Santra, A., & Mitra, S. S. (2020). Semi-automated impervious feature extraction using built-up indices developed from space-borne optical and SAR remotely sensed sensors. *Advances in Space Research*, 66(6), 1372-1385. https://doi.org/10.1016/j.asr.2020.05.040

Sinha, S., Sharma, L. K., & Nathawat, M. S. (2013). Integrated geospatial techniques for land-use/land-cover and forest mapping of deciduous Munger forests (India). *Universal Journal of Environmental Research & Technology,* 3(2), 190-198.

Sinha, S., Sharma, L. K., & Nathawat, M. S. (2015). Improved Land-use/Land-cover classification of semi-arid deciduous forest landscape using thermal remote sensing. *The Egyptian Journal of Remote Sensing and Space Science*, 18(2), 217-233. https://doi.org/10.1016/j.ejrs.2015.09.005

Subhani, R., & Ahmad, M. M. (2019). Socio-economic impacts of cyclone aila on migrant and non-migrant households in the southwestern coastal areas of Bangladesh. *Geosciences*, 9(11), 482. https://doi.org/10.3390/geosciences9110482

Talukdar, S., Singha, P., Mahato, S., Pal, S., Liou, Y. A., & Rahman, A. (2020). Land-use land-cover classification by machine learning classifiers for satellite observations—A review. *Remote sensing*, 12(7), 1135. https://doi.org/10.3390/rs12071135

UNISDR. (2013). United Nations International Strategy for Disaster Reduction (UNISDR). In HFA-Asia Pacific, (2011–2013), Hyogo Framework for Action in Asia and the Pacific; UNISDR.

United Nations. (2009) Risk and Poverty in Changing Climate Global Assessment Report on Disaster Risk Reduction; United Nations: Geneva, Switzerland.

Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., ... & Somerville, R. (2014). Ch. 2: Our changing climate. Climate change impacts in the United States: The third national climate assessment, 19-67.

Wang, Q. B., Xu, W., Xue, Q. Z., & Su, W. A. (2010). Transgenic Brassica chinensis plants expressing a bacterial codA gene exhibit enhanced tolerance to extreme temperature and high salinity. *Journal of Zhejiang University Science B*, 11(11), 851-861. https://doi.org/10.1631/jzus.B1000137

Wong, P. P., Losada, I. J., Gattuso, J. P., Hinkel, J., Khattabi, A., McInnes, K. L., Saito, Y., & Sallenger, A. (2014). Coastal systems and low-lying areas. *Climate change*, 2104, 361-409.

Yodmani, S. (2001). Disaster risk management and vulnerability reduction: Protecting the poor. New York: The Center.

Younus, M. A. F., & Harvey, N. (2014). Economic consequences of failed autonomous adaptation to extreme floods: A case study from Bangladesh. *Local Economy*, 29(1-2), 22-37. https://doi.org/10.1177/0269094213515175

Younus, M.A.; Sharna, S.S.; Rahman, T.B. (2013, November) Integrated assessment and decision-support tool for community-based vulnerability and adaptation to storm surges in four coastal areas in Bangladesh [Paper presentation]. Proceedings of the Australia New Zealand Society for Ecological Economics 2013 Conference, Canberra, Australia.

Zafar, Z., Zubair, M., Zha, Y., Fahd, S., & Nadeem, A. A. (2024). Performance assessment of machine learning algorithms for mapping of land use/land cover using remote sensing data. *The Egyptian Journal of Remote Sensing and Space Sciences*, 27(2), 216-226.